**Module 16.17 The eukaryotic cell probably originated as a community of prokaryotes.**

1. The fossil record indicates that the first eukaryotes evolved approximately 2.1 bya.
   1. There are two theories of how the membrane-enclosed organelles arose.
      1. The **first theory** is that the ***endomembrane system*** is thought to have evolved by membrane infolding and resulted in the specialization of internal membranes into membrane-bounded organelles (Figure 16.17A) except mitochondria and chloroplasts.

Review: The endomembrane system is described in Modules 4.5–4.13.

* + 1. The **second theory** involves the concept of *symbiosis*. The close association between two organisms of different species is referred to as symbiosis. Endosymbiosis is the likely basis of the origin of mitochondria and chloroplasts (Figure 16.17B), with mitochondria evolving first. The ancestral mitochondria may have been small heterotrophic prokaryotes, and similarly, the ancestral chloroplasts may have been small photosynthetic prokaryotes.
    2. Several lines of evidence support the endosymbiotic hypothesis. Mitochondria and chloroplasts are similar in size and shape to prokaryotes and include bacterial-type DNA, RNA, and ribosomes. These organelles replicate in eukaryotic cytoplasm in a manner resembling binary fission. The inner, but not the outer, membranes of these organelles contain enzymes and electron transport molecules characteristic of prokaryotes, not eukaryotes.

NOTE: Endosymbiosis is common today among protists and/or prokaryotes.